Unilateral robotic hybrid mini-maze: A novel experimental approach

Article *in* International Journal of Medical Robotics and Computer Assisted Surgery · March 2015

Impact Factor: 1.53 · DOI: 10.1002/rcs.1649 · Source: PubMed

Badi Rawashdeh

The University of Arizona

Duy Nguyen

George Washington University

Robert S Poston

The University of Arizona

Farid Gharagozloo

The University of Arizona

The International Journal of **Medical Robotics** and **Computer Assisted Surgery**

THE INTERNATIONAL JOURNAL OF MEDICAL ROBOTICS AND COMPUTER ASSISTED SURGERY
Int J Med Robotics Comput Assist Surg (2015)
Published online in Wiley Online Library (wileyonlinelibrary.com) **DOI:** 10.1002/rcs.1649

ORIGINAL ARTICLE

Unilateral robotic hybrid mini-maze: a novel experimental approach

Mohammad Moslemi*
Badi Rawashdeh
Mark Meyer
Duy Nguyen
Robert Poston
Farid Gharagozloo

Division of Cardiothoracic Surgery, University of Arizona Medical Center, Tucson, AZ, USA

*Correspondence to:
Mohammad Moslemi, Division of Cardiothoracic Surgery, University of Arizona Medical Center, 1501 N. Campbell Avenue, PO Box 245071, Tucson, AZ 85724–5071, USA.
E-mail: Moslemi1981@gmail.com

Accepted: 29 January 2015

Abstract

Background A complete Cox maze IV procedure is difficult to accomplish using current endoscopic and minimally invasive techniques. These techniques are hampered by inability to adequately dissect the posterior structures of the heart and place all necessary lesions. We present a novel approach, using robotic technology, that achieves placement of all the lesions of the complete maze procedure.

Methods In three cadaveric human models, the technical feasibility of using robotic instruments through the right chest to dissect the posterior structures of the heart and place all Cox maze lesions was performed.

Results The entire posterior aspect of the heart was dissected in the cadaveric model facilitating successful placement of all Cox maze IV lesions with robotic assistance through minimally invasive incisions.

Conclusion The robotic Cox maze IV procedure through the novel right thoracic approach is feasible. This obviates the need for sternotomy and avoids the associated morbidity of the conventional Cox-maze procedure. Copyright © 2015 John Wiley & Sons, Ltd.

Keywords atrial fibrilation (AF); Cox maze; arrhythmia; robotic

Introduction

Atrial fibrillation (AF) is the most common sustained arrhythmia of the heart. Globally, it affects about 1% of the general population and is seen in over 2 and 6 million people in the USA and the EU, respectively (1-4). There is a 1 in 6 lifetime chance for developing AF, even in the absence of cardiac disease, and this risk increases with age (2).

The Cox-maze procedure has been shown to be effective in controlling AF (5). However, widespread application of this technique in patients with lone AF has been limited by the morbidity of a median sternotomy and the need for cardiopulmonary bypass (6). Consequently, in the vast majority of patients medical therapy is chosen over surgery. In an attempt to offer the Cox-maze technique to a larger population of patients with lone AF, multiple minimally invasive approaches have been proposed. These procedures are designed to avoid a median sternotomy by accessing the heart through video-assisted techniques (7-11). However, these procedures have been hampered by the limitations of conventional videoendocoscopic instruments, the inherent steep learning curve of learning minimally invasive techniques, poor visualization due to two-dimensional (2D) imaging, poor dexterity because of limited range of motion, and the need for bilateral chest incisions. The most important shortcoming has been the inconsistent results due to incomplete lesion sets when compared to the standard Cox-maze procedure (7-9,11-15).

Currently, to the best of our knowledge, no attempt has been made to utilize robotic technology in order to overcome the limitations of these previously developed minimally invasive approaches for the complete Cox maze IV. Surgical robotics offers the advantages of magnified three-dimensional (3D) visualization and better instrument manoeuvrability within the confined space of the thorax and mediastinum. We hypothesize that both sides of the left atrium back and left atrial appendage are accessible using a robotic approach through the right chest, following dissection of the subcarinal space. This paper outlines the surgical technique developed to perform a complete robotic Cox maze IV procedure through four ports in the right chest in a cadaveric model.

Methods

The following procedure was performed on three human cadavers to assess the feasibility of a one-sided approach for a robotic unilateral transthoracic Cox maze IV procedure.

Set-up and positioning

The cadaver is placed in left lateral decubitus position with arms orientated perpendicular to the body; four trocars are placed (Figure 1):

- First trocar is placed at the mid axillary line in the eighth intercostal space.
- Second trocar at the anterior axillary line in the sixth intercostal space
- Third trocar at the posterior axillary line in the fifth intercostal space
- Fourth trocar at the anterior axillary line in the seventh intercostal space

An endo-paddle (Covidien Inc., New Haven, CT, USA) retractor is introduced in port number 4 and used to retract the lung anteromedially, thereby exposing the subcarinal space. This retractor is fixed to the table using a Fast Clamp (Snowden Pencer, PA, USA).

The robot is brought in from over the head and a 30° down-viewing camera is placed through port number 1. A hook cautery is placed in the right robotic arm and introduced through port number 2. An EndoGrasper is placed in the left arm an introduced through port number 3.

Dissection of the posterior heart and access to the left atrium

Dissection of the subcarinal space starts with dividing the pleura overlying this space. The oesophagus is identified

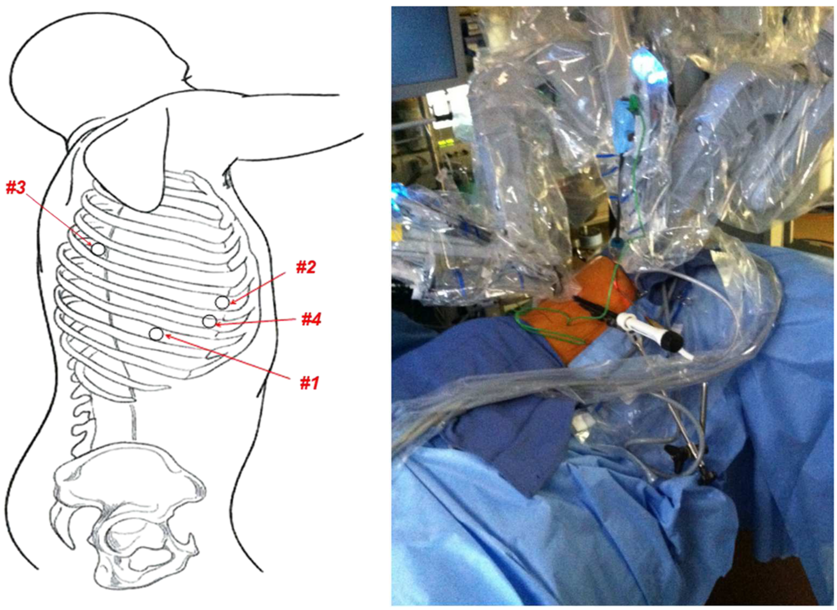

Figure 1. Left lateral decubitus position of model with arm positioned perpendicular to body; trocars are placed and robot arms in position

DOI: 10.1002/rcs

and retracted laterally and posteriorly by the table assistant, using Yankauer suction. The border of the right main stem bronchus is identified and dissection continues toward the carina. The left main bronchus is also identified and dissected. The subcarinal nodal bundle is removed, thereby exposing the posterior aspect of the pericardium (Figure 2).

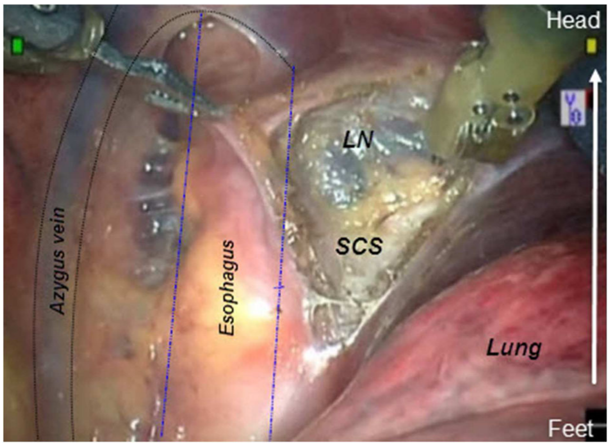

Figure 2. Dissection of subcarinal space and excision of subcarinal nodal bundle: SCS, subcarinal space; LN, lymph node

The pericardium is opened and stay sutures (0 Ethibond) are used to retract the edges of the pericardium medially and laterally, exposing the posterior aspect of the left atrium (Figure 3).

Isolation of pulmonary veins

The left superior and inferior pulmonary veins are dissected and encircled with a vessel loop. A third vessel loop is used to encircle the both pulmonary veins at their junction with the left atrium. The coronary sinus is visualized and the site for the isthmus lesion is marked (Figure 4).

The right inferior pulmonary vein is dissected and encircled with a vessel loop. In order to visualize and encircle the right superior pulmonary vein, the retractor is removed and the lung is reflected posteriorly. Then a vessel loop is used to encircle the right superior pulmonary vein. A third vessel loop is used to encircle both right superior and inferior pulmonary veins at their confluence and entry to the left atrium. This manoeuvre allows the right and left pulmonary veins to be isolated in pairs.

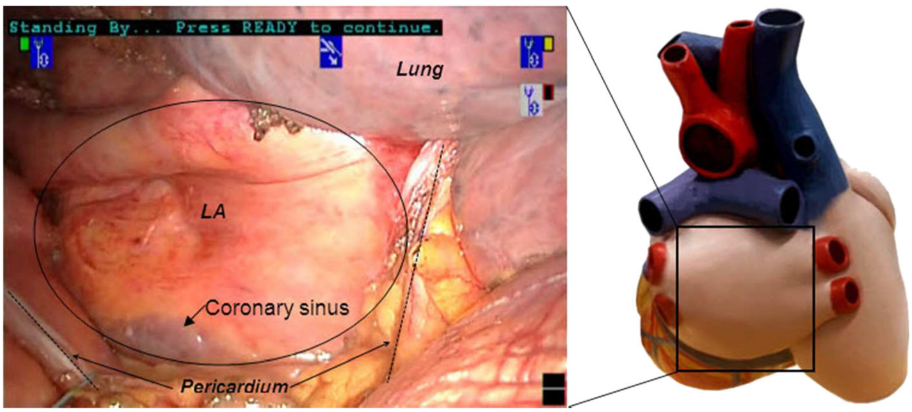

Figure 3. Posterior aspect of the heart: LA, left atrium

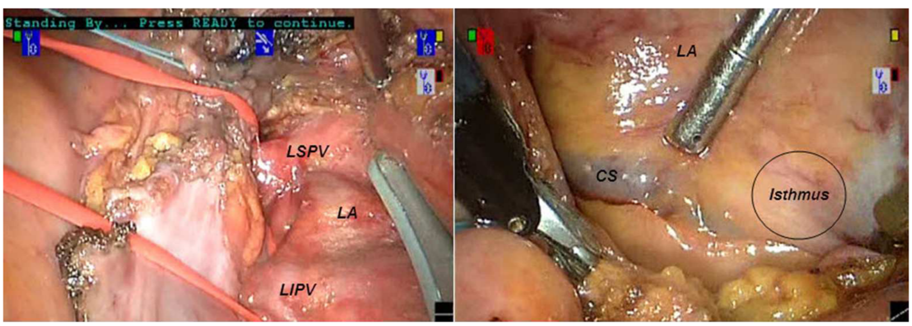

Figure 4. Left pulmonary veins isolation and isthmus lesion site: LSPV, left superior pulmonary vein; LIPV, left inferior pulmonary vein; CS, coronary sinus; LA, left atrium

DOI: 10.1002/rcs

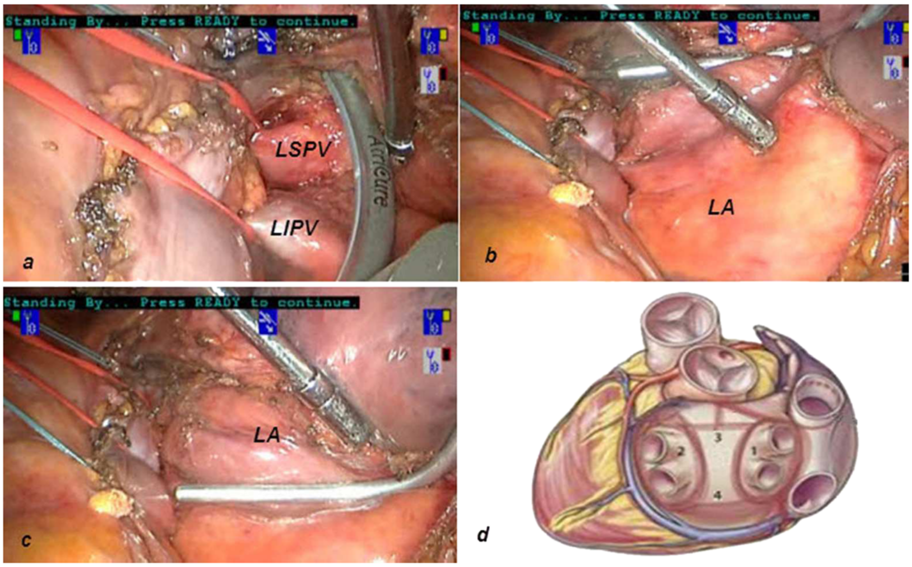

Figure 5. (a) Pulmonary vein lesion; (b, c) box lesion; (d) schematic box lesion: LSPV, left superior pulmonary vein; LIPV, left inferior pulmonary vein; LA, left atrium

Placement of left-sided lesions

An Atricure (Atricure Inc., Cincinnati, OH, USA) radiofrequency (RF) clamp is used to place the lesion set at the junction of pulmonary veins and the left atrium (lesions 1 and 2). Then the box lesion on the back of the left atrium is completed by using a radiofrequency probe, which connects these ablation lines superiorly and inferiorly (lesions 3 and 4). Next, using a radiofrequency probe, a lesion is placed on the dome of the left atrium, extending superiorly from lesion number 3 (Figure 5).

Finally, a radiofrequency probe (Atricure) is used to place a lesion on the isthmus (Figure 6).

Left atrial appendage exclusion

The dissection of the posterior mediastinum and left-sided pulmonary veins allows the left atrial appendage to be delivered into the right chest through the space between the left superior and inferior pulmonary veins. Atrial appendage clips (Atricure) are then used to exclude the left atrial appendage at its junction with the left atrium (Figure 7).

Figure 6. Placing isthmus lesion using a radiofrequency probe

Placement of right-sided lesions

Following the completion of the left sided lesions, the lung is reflected posteriorly. The pericardium is opened posterior to the phrenic nerve, pericardial stay sutures are placed and right-sided lesions are placed in the following manner:

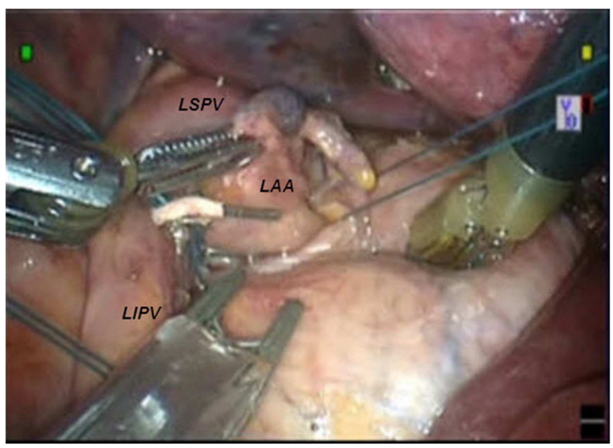

Figure 7. Left atrial appendage exclusion by clips after delivering to the right chest through the space between left superior and inferior pulmonary veins: LSPV, left superior pulmonary vein; LIPV, left inferior pulmonary vein; LAA, left atrial appendage

DOI: 10.1002/rcs

Figure 8. Schematic lesion set done through posterior approach

1. From the upper portion of the right atrium at the confluence with the superior vena cava (SVC) onto the SVC.
2. From the confluence of SVC and the right atrium onto the body of the RA, extending to the inferior vena cava (IVC).
3. From the junction of the IVC and RA continuously to the atrioventricular groove.

The tricuspid lesion can be done through a catheter by the cardiologist. This completes the robotic lesion sets via a right transthoracic approach (Figure 8).

Discussion

The maze procedure was introduced by James Cox in 1987 in an attempt to disrupt the histological substrate needed for initiation and maintenance of atrial fibrillation. Since then, this area of cardiac surgery has been under constant change. After some modification, the original procedure has evolved into maze III and became the gold standard for surgical treatment of atrial fibrillation (5). Although effective in treatment of AF, this procedure traditionally requires median sternotomy and cardiopulmonary bypass. Because of the morbidity associated with the maze procedure, the majority of patients with lone AF are treated by a combination of anti-arrhythmic and anticoagulant agents in a purely palliative approach. In an attempt to increase the application of the Cox maze procedure, a number of minimally invasive procedures have been proposed.

In 2004, Damiano and coworkers (16) used bipolar radiofrequency ablation and cryoablation to replicate the majority of lesions that were originally made by 'cut and sew' in Cox maze III and introduced the fourth version of this surgical method. This technique was performed through a median sternotomy and necessitated cardiopulmonary bypass. Later, in 2010, Lee and coworkers (17) described the minimally invasive Cox maze IV procedure through a right mini-thoracotomy.

In 2004 Ad and Cox (10) reported a modified maze procedure called minimally invasive maze III, using a 7 cm right anterior thoractomy approach. In this method, after initiation of cardiopulmonary bypass and cardiac arrest, the right atrium was entered using the site of right atrial appendage excision. After placing the right-sided lesions by cryoablation, the left atrium was entered through a standard atriotomy in order to place the left-sided lesions.

In 2005, Wolf and coworkers (11) reported their experience with video-assisted thoracoscopic AF surgery. Their procedure required the patient to be placed in right and left lateral decubitus subsequently, and then the bipolar RF clamp was introduced into the chest under thoracoscopic visualization to apply the lesions around each pair of pulmonary veins. Afterwards, the left atrial appendage was removed using a surgical stapler.

Attempts were made to make the AF surgery as minimally invasive as possible by using bilateral totally endoscopic approaches to isolate pulmonary veins and exclude the left atrial appendage (15), but unfortunately they were not associated with satisfactory results. Pruitt *et al*. (18) reported a rate of 9% failure in pulmonary vein isolation. These techniques were hampered by the need for a bilateral transthoracic approach, blind dissection of intrapericardial structures and inconsistent results. The most important shortcoming of the present minimally invasive techniques is the inability to perform a complete Cox maze IV procedure using the conventional video-endoscopic techniques.

Limited manoeuvrability, low degree of freedom and lack of depth perception, caused by 2D visualization (19), make conventional thoracoscopic approach an inconvenient measure for surgical treatment of AF. Wristed movements and highly magnified 3D visualization has made robots appealing for this purpose. Loulmet *et al*. (20) were the first to use a robot to deliver microwave energy in an attempt to isolate pulmonary veins in a patient with paroxysmal AF. They used the robot for dissections and placement of a Flex 10 (Afx Inc.) around the pulmonary veins. A conventional endoscopic instrument was introduced into the left chest in order to rectify the position of the ablative probe. The patient experienced recurrent atrial flutter 8 months after the procedure, presumably because of lack of mitral and tricuspid valve isthmus lesions. Others have used the robot to manipulate and position the microwave probe against the left atrium as well as for left atrial appendage exclusion (21,22).

DOI: 10.1002/rcs

As one of the latest attempts, Cheema *et al*. (23) have reported a successful robotic endoscopic cryomaze. They placed a full set of left-side maze lesions endocardially, using an argon-based cryocatheter, and oversewed the left atrial appendage through the left atriotomy.

All methods mentioned have some shortcomings. These methods require either some degree of chest wall incision or are dependent on a bilateral approach. Moreover, many of these methods do not perform a complete Cox maze lesion set. The most direct approach to performing a complete Cox maze IV is through direct visualization of the intrapericardial structures from the posterior aspect of the heart. We present a novel minimally invasive approach which can replicate the Cox maze IV completely. Facilitated by the inherent advantages of robotic surgical technology, this method offers several key advantages over the previous minimally invasive procedures:

1. It is a unilateral approach, obviating the need for multiple ports on both sides of the chest; the left atrium is accessed via the right chest after dissection of the subcarinal space.
2. Using robots with high manoeuvrability, highly magnified 3D visualization and fine tremor-filtered movement diminishes the risk of collateral damage and bleeding.
3. The right and left pulmonary veins are dissected and the isthmus lesion is placed under direct visualization.
4. This approach provides direct visualization of the posterior aspect of the heart, enabling the surgeon to precisely dissect the right and left pulmonary veins and place the isthmus lesion under direct visualization.
5. Using the posterior approach with the robotic technology, the left atrial appendage can be delivered into the right chest and can be excluded under direct visualization.
6. It offers a combination of minimum invasiveness with the ability to perform both right- and left-side lesion sets.
7. This can be done off-pump, which obviates the need for heparinization, which may be problematic or contra-indicated in some patients.

This paper outlines the feasibility of this technique in three cadaveric models and will be applied to carefully selected patients in an investigational protocol in the clinical setting.

Limitations

Our experience on cadaveric models was limited by the lack of physiological and haemodynamic components. Moreover, the electrophysiological results of this procedure could not be assessed. Transmurality of the lesions should be assessed, especially if the procedure is being done off-pump. Utilization of an animal model to reproduce the same technique in an *in vivo* model is not helpful, due to anatomical differences that do not accurately represent the dissection in a human body. Placement of isthmus lesions is also challenging and demands the cooperation of cardiologist for a hybrid approach.

The decompressed cadaveric heart allows access to the pulmonary veins and the left atrial appendage. These manoeuvres would be difficult in the live patient and, most likely, would require the use of partial cardiopulmonary bypass and cardiac decompression for the period of dissection.

Radiofrequency probes were used to complete the procedure. This was based on the authors' experience. Naturally, once the structures are dissected with the use of robotics, other devices and energy sources can be used.

Implementation of this technique in carefully selected patients is needed to assess the results, postoperative complications, risk:benefit ratio, hospital stay and economic issues of this new method.

Conclusion

A robotic unilateral minimally invasive surgical approach for treatment of atrial fibrillation is feasible and justified, especially in patients with lone AF who desire reliable definitive treatment that also avoids the morbidity, mortality and cosmetic issues associated with the more conventional approaches.

Acknowledgements

The authors would like to thank Dr Zain Khalpey, MD, for his revision, and Barbara Tempesta, CRNP, and Keith Maas, CSA, for their dedicated contribution to this paper.

Conflict of interest

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

Funding

No specific funding.

DOI: 10.1002/rcs

References

1. Ghavidel AA, Javadpour H, Shafiee M, *et al.* Cryoablation for surgical treatment of chronic atrial fibrillation combined with mitral valve surgery: a clinical observation. *Eur J Cardiothorac Surg* 2008; **33**(6): 1043–1048.
2. Lloyd-Jones DM, Wang TJ, Leip EP, *et al.* Lifetime risk for development of atrial fibrillation the Framingham heart study. *Circulation* 2004; **110**(9): 1042–1046.
3. Roger VL, Go AS, Lloyd-Jones DM, *et al.* Heart disease and stroke statistics – 2012 update: a report from the American Heart Association. *Circulation* 2012; **125**(1): e2–220.
4. Camm AJ, Kirchhof P, Lip GY, *et al.* Guidelines for the management of atrial fibrillation: the Task Force for the Management of Atrial Fibrillation of the European Society of Cardiology (ESC). *Eur Heart J* 2010; **31**(19): 2369–2429.
5. Saint L, Damiano R, Jr. Surgical treatment of atrial fibrillation. *Missouri Med* 2011; **109**(4): 281–287.
6. Prasad SM, Maniar HS, Camillo CJ, *et al.* The Cox maze III procedure for atrial fibrillation: long-term efficacy in patients undergoing lone versus concomitant procedures. *J Thorac Cardiovasc Surg* 2003; **126**(6): 1822–1827.
7. Bauer M, Hetzer R. Video-assisted thoracoscopic surgical treatment of lone atrial fibrillation. *Multimed Man Cardiothorac Surg* 2009; **2009**(1127): 1–10.
8. Bagge L, Blomström P, Nilsson L, *et al.* Epicardial off-pump pulmonary vein isolation and vagal denervation improve long-term outcome and quality of life in patients with atrial fibrillation. *J Thorac Cardiovasc Surg* 2009; **137**(5): 1265–1271.
9. Edgerton JR, Edgerton ZJ, Weaver T, *et al.* Minimally invasive pulmonary vein isolation and partial autonomic denervation for surgical treatment of atrial fibrillation. *Ann Thorac Surg* 2008; **86**(1): 35–39.
10. Ad N, Cox JL. The Maze procedure for the treatment of atrial fibrillation. *J Card Surg* 2004; **19**(3): 196–200.
11. Wolf RK, Schneeberger EW, Osterday R, *et al.* Video-assisted bilateral pulmonary vein isolation and left atrial appendage exclusion for atrial fibrillation. *J Thorac Cardiovasc Surg* 2005; **130**(3): 797–802.
12. Li X, Wang J, Ferguson MK. Competence versus mastery: the time course for developing proficiency in video-assisted thoracoscopic lobectomy. *J Thorac Cardiovasc Surg* 2014; **147**(4): 1150–1154.
13. Kaul S, Shah NL, Menon M. Learning curve using robotic surgery. *Curr Urol Rep* 2006; **7**(2): 125–129.
14. Bodner J, Wykypiel H, Wetscher G, *et al.* First experiences with the da Vinci™ operating robot in thoracic surgery. *Eur J Cardiothorac Surg* 2004; **25**(5): 844–851.
15. Pruitt JC, Lazzara RR, Dworkin GH, *et al.* Totally endoscopic ablation of lone atrial fibrillation: initial clinical experience. *Ann Thorac Surg* 2006; **81**(4): 1325–1331.
16. Damiano RJ, Jr, Gaynor SL. Atrial fibrillation ablation during mitral valve surgery using the Atricure™ device. *Op Tech Thorac Cardiovasc Surg* 2004; **9**(1): 24–33.
17. Lee AM, Clark K, Bailey MS, *et al.* A minimally invasive Cox-maze procedure: operative technique and results. *Innovations (Phila)* 2010; **5**(4): 281–286.
18. Pruitt JC, Lazzara RR, Ebra G. Minimally invasive surgical ablation of atrial fibrillation: the thoracoscopic box lesion approach. *J Intervent Card Electrophysiol* 2007; **20**(3): 83–87.
19. Mandal K, Alwair H, Wiley Nifong L, *et al.* Robotically assisted minimally invasive mitral valve surgery. *J Thorac Dis* 2013; **5** (suppl 6): S694.
20. Loulmet DF, Patel NC, Patel NU, *et al.* First robotic endoscopic epicardial isolation of the pulmonary veins with microwave energy in a patient in chronic atrial fibrillation. *Ann Thorac Surg* 2004; **78**(2): e24–25.
21. Bolotin G, Kypson AP, Wiley Nifong L, *et al.* Robotically-assisted left atrial fibrillation ablation and mitral valve repair through a right mini-thoracotomy. *Ann Thorac Surg* 2004; **78**(4): e63–64.
22. Reade CC, Johnson JO, Bolotin G, *et al.* Combining robotic mitral valve repair and microwave atrial fibrillation ablation: techniques and initial results. *Ann Thorac Surg* 2005; **79**(2): 480–484.
23. Cheema FH, Weisberg JS, Khalid I, *et al.* Warm beating heart, robotic endoscopic Cox-cryomaze: an approach for treating atrial fibrillation. *Ann Thorac Surg* 2009; **87**(3): 966–968.

DOI: 10.1002/rcs